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(54) **SOLAR ARRAY WING**

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CPC ***H02S 30/20*** (2014.12); ***B64G 1/222*** (2013.01); ***B64G 1/443*** (2013.01); ***H02S 20/30*** (2014.12)

(58) **Field of Classification Search**
CPC ... B64G 1/443; B64G 1/22–229; H02S 30/20; H02S 20/30
See application file for complete search history.

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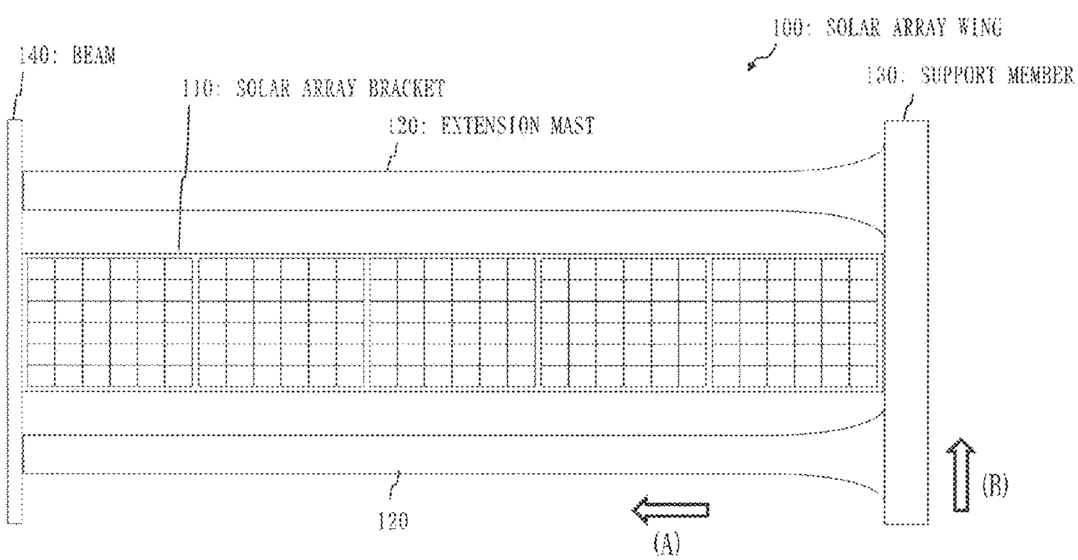
(57) **ABSTRACT**

A solar array wing includes an extension mast to be extended from a wound state, and a support member, around which the extension mast is wound, to support the extension mast after the extension mast is extended. The support member is made of a fiber reinforced composite material. A coefficient of linear expansion of the fiber reinforced composite material, a unit of which is for each degree Celsius, in a direction that is orthogonal to an extension direction of the extension mast, is higher than or equal to -1×10^{-6} and lower than or equal to 1×10^{-6}.

10 Claims, 3 Drawing Sheets



(51) **Int. Cl.**

B64G 1/44	(2006.01)
H02S 20/30	(2014.01)

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Fig. 1

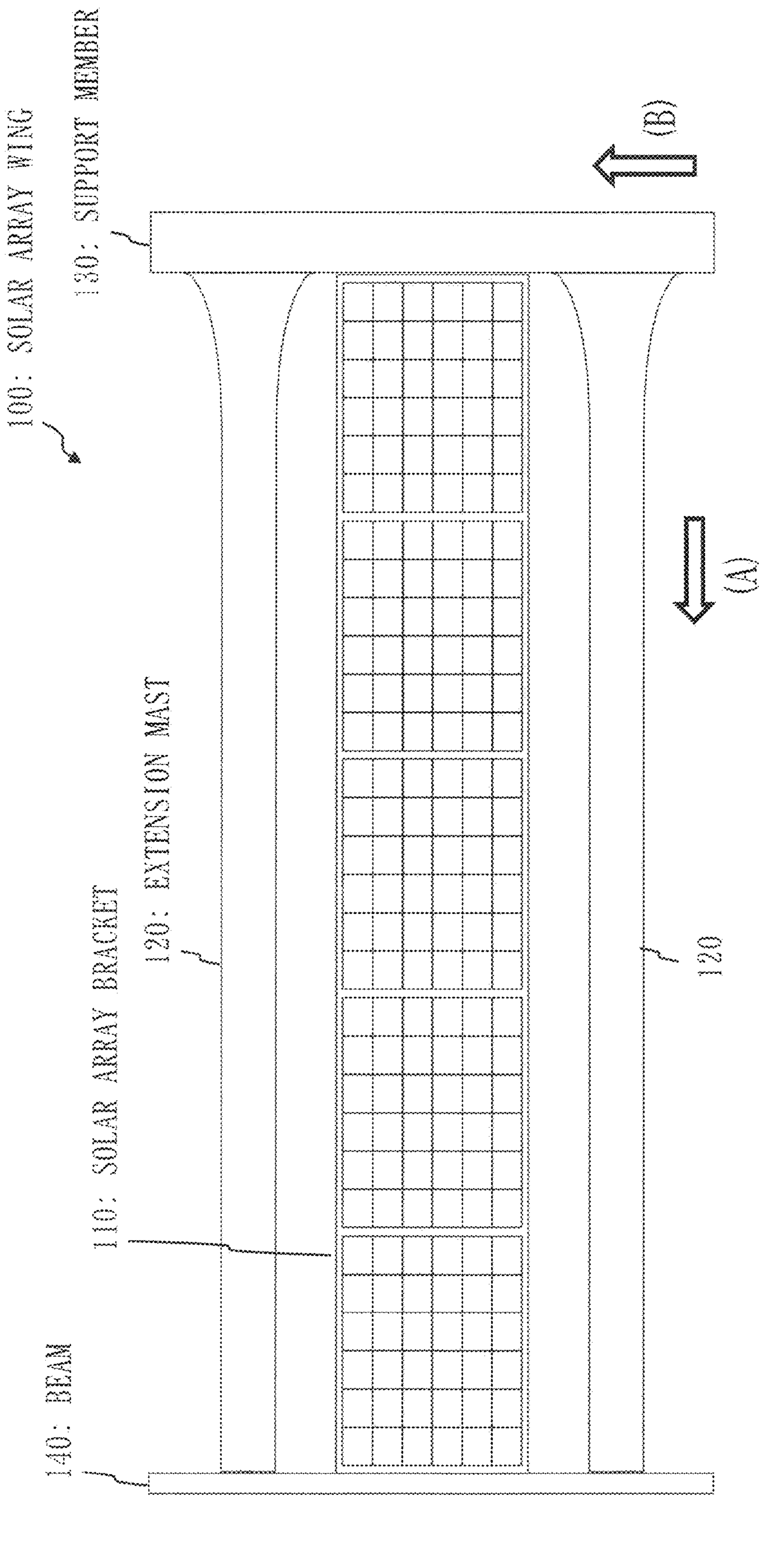

100: SOLAR ARRAY WING
130: SUPPORT MEMBER
(B)
(A)
120: EXTENSION MAST
110: SOLAR ARRAY BRACKET
120
140: BEAM

Fig. 2

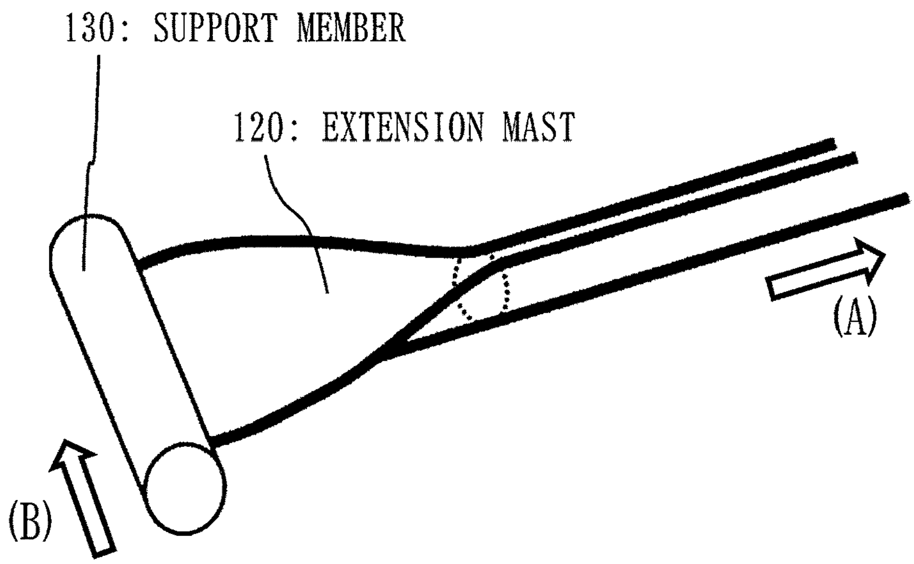

130: SUPPORT MEMBER
120: EXTENSION MAST
(A)
(B)

Fig. 3

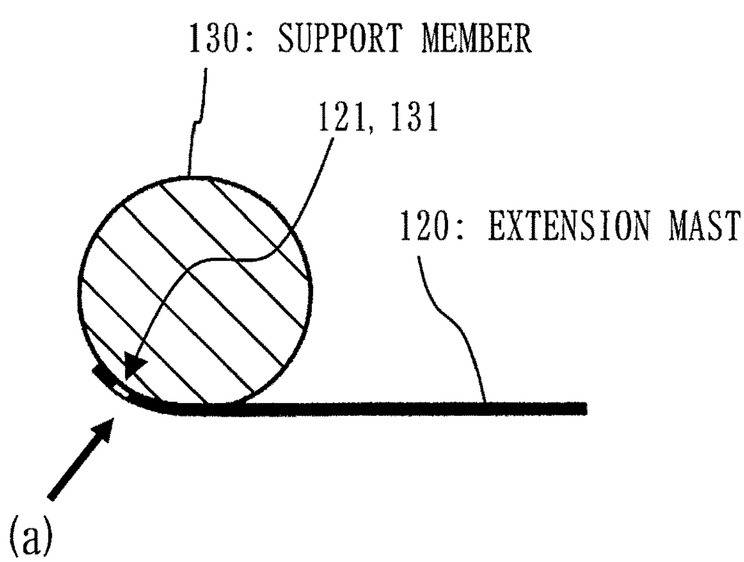

130: SUPPORT MEMBER
121, 131
120: EXTENSION MAST
(a)

Fig. 4

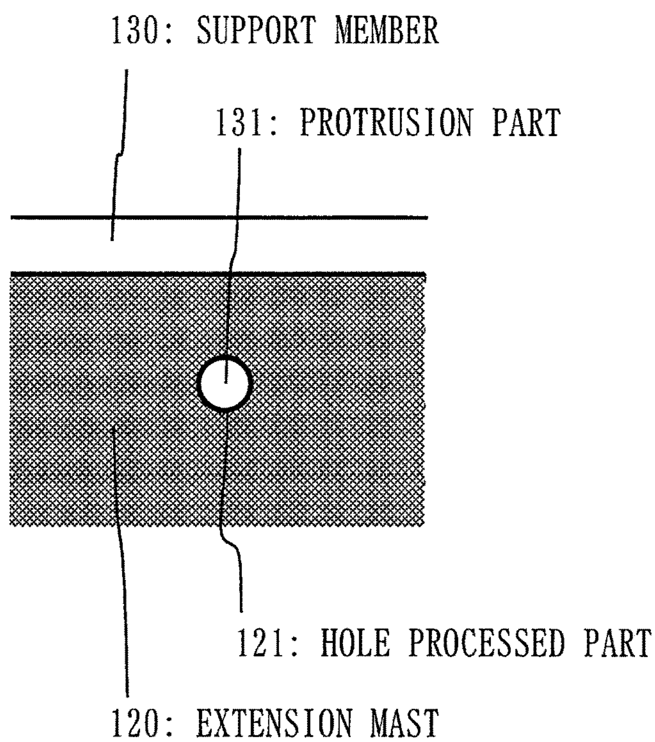
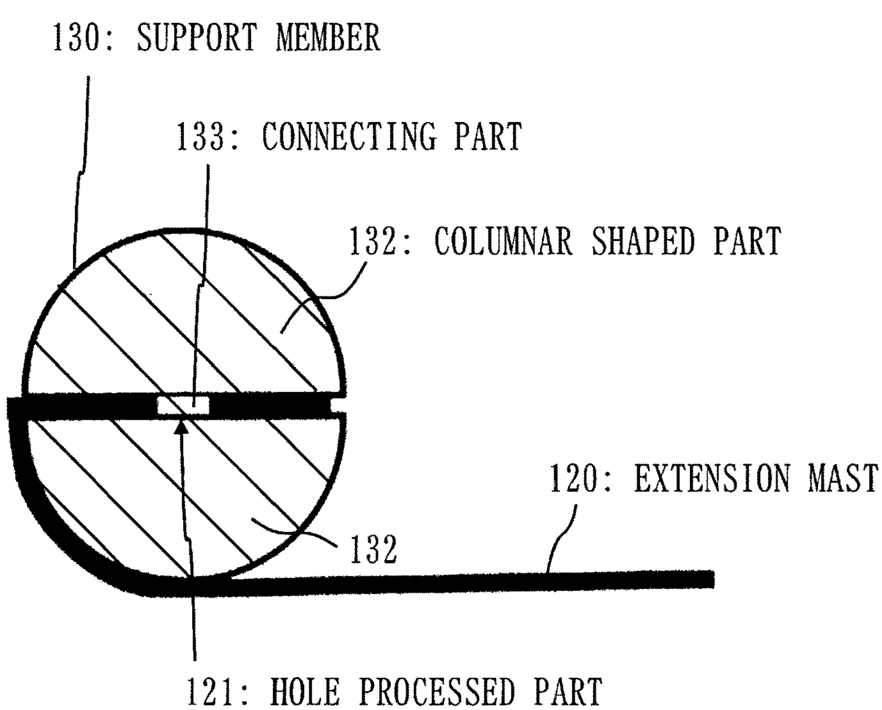

130: SUPPORT MEMBER
131: PROTRUSION PART
121: HOLE PROCESSED PART
120: EXTENSION MAST

Fig. 5


130: SUPPORT MEMBER
133: CONNECTING PART
132: COLUMNAR SHAPED PART
120: EXTENSION MAST
132
121: HOLE PROCESSED PART

SOLAR ARRAY WING

CROSS-REFERENCE TO RELATED APPLICATION

The present application is based on PCT filing PCT/JP2020/017785, filed Apr. 24, 2020, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a solar array wing.

BACKGROUND ART

Due to an artificial satellite needing a large amount of power, increase in size of the solar array wing is in demand.

In recent years, a method in which a power generation panel is stored cylindrically, the power generation panel is expanded by extending a mast, and the power generation panel is retained by the mast, is being considered. Utilizing carbon fiber reinforced plastic (CFRP) for the mast is being considered.

In this method, a discrepancy in extension directions of both the power generation panel and the mast leads to damage to the power generation panel.

Consequently, an angle error in the extension direction and an angle change in the extension direction are necessary to be reduced.

Reducing a thermal expansion difference between the mast and a support member to which the mast is joined is effective in reducing the angle error in the extension direction and the angle change in the extension direction. This thermal expansion difference occurs due to a temperature change. Reducing a clearance in a joining part between the mast and the support member is effective in reducing the angle error in the extension direction and the angle change in the extension direction.

Patent Literature 1 discloses a joining method in which an insert part of a metal cylindrical body is inserted into a CFRP cylindrical body, and both cylindrical bodies are adhered to each other by an adhesive.

CITATION LIST

Patent Literature

Patent Literature 1: JP H01-114421 A

SUMMARY OF INVENTION

Technical Problem

Measures such as reducing the thermal expansion difference between the mast and the support member, and reducing the clearance in the joining part between the mast and the support member, are effective in reducing the angle error and the angle change in the extension direction of both the power generation panel and the mast.

In a current situation, however, there is no technology that enables these measures. Instead, when rigidity of the support member is increased by making a structure of the support member larger, weight of the support member increases.

An issue such as below exists in the joining method disclosed in Patent Literature 1.

Since a thermal expansion difference exists between CFRP and metal, a shape of a joining part between a CFRP member and a metal member changes according to a temperature change. Consequently, an extension direction of the CFRP member changes according to a change in environment. The extension direction of the CFRP member can change as much as an amount of clearance between the CFRP member and the metal member. These changes become factors for an angle error occurring in the extension direction.

The present disclosure aims to make an angle error between an extension direction of a power generation panel and an extension direction of an extension mast smaller.

Solution to Problem

A solar array wing according to the present disclosure includes:

- an extension mast to be extended from a wound state; and
- a support member, around which the extension mast is wound, to support the extension mast after the extension mast is extended.

The support member is made of a fiber reinforced composite material.

A coefficient of linear expansion of the fiber reinforced composite material, a unit of which is for each degree Celsius, in a direction that is orthogonal to an extension direction of the extension mast, is higher than or equal to -1×10^{-6} and lower than or equal to 1×10^{-6}.

Advantageous Effects of Invention

According to the present disclosure, since deformation of a support member is reduced, an angle error between an extension direction of a solar array bracket (a power generation panel) and an extension direction of an extension mast can be made smaller.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic view of a solar array wing **100** according to Embodiment 1.

FIG. **2** is a perspective view illustrating an end part of a support member **130** according to Embodiment 1.

FIG. **3** is a cross-sectional view of a joining portion between the support member **130** and an extension mast **120** according to Embodiment 1.

FIG. **4** is an enlarged view of the joining portion between the support member **130** and the extension mast **120** according to Embodiment 1.

FIG. **5** is a cross-sectional view of a joining portion between a support member **130** and an extension mast **120** according to Embodiment 2.

DESCRIPTION OF EMBODIMENTS

In the embodiments and in the drawings, the same reference signs are added to the same elements or corresponding elements. Description of elements having the same reference signs added as the elements described will be suitably omitted or simplified.

Embodiment 1

A solar array wing **100** will be described based on FIG. **1** to FIG. **4**.

A configuration of the solar array wing **100** will be described based on FIG. **1**. FIG. **1** illustrates the solar array wing **100** in an extended state.

The solar array wing **100** includes a solar array bracket **110**, two extension masts **120**, a support member **130**, and a beam **140**.

The solar array bracket **110** is a flexible power generation panel. The power generation panel is also called a solar cell panel.

The extension mast **120** is a mast made of carbon fiber reinforced plastic (CFRP).

The extension mast **120** is extended from a state in which the extension mast **120** is wound around the support member **130**.

The two extension masts **120** are positioned one on each side of the solar array bracket **110** in a width direction (direction (B)) of the solar array bracket **110**.

The support member **130** is a member for supporting the solar array bracket **110** and the two extension masts **120**.

The support member **130** forms a columnar shape. Specifically, the support member **130** forms a cylindrical shape.

One end part of the solar array bracket **110** in a length direction (direction (A)) of the solar array bracket **110** is attached to the support member **130**. One end part of the extension mast **120** in a length direction (direction (A)) of each extension mast **120** is attached to the support member **130**.

The beam **140** is a member for supporting the solar array bracket **110** and the two extension masts **120**.

Another end part of the solar array bracket **110** in the length direction of the solar array bracket **110** is attached to the beam **140**. Another end part of the extension mast **120** in the length direction of each extension mast **120** is attached to the beam **140**.

The solar array wing **100** is attached mainly to a spacecraft such as an artificial satellite and used.

At a time of storing the solar array wing **100**, the solar array bracket **110** and the two extension masts **120** are wound around the support member **130**. That is, the solar array bracket **110** and the two extension masts **120** are stored in a shortened state where the solar array bracket **110** and the two extension masts **120** are wound around the support member **130**.

At a time of extending the solar array wing **100**, the beam **140** is moved in a direction away from the support member **130**. As a result, the solar array bracket **110** and the two extension masts **120** are extended.

Arrow (A) indicates an extension direction of the solar array bracket **110** and the two extension masts **120**.

Arrow (B) indicates a direction that is orthogonal to the extension direction that arrow (A) indicates and a length direction of the support member **130**.

A material for the support member **130** will be described based on FIG. **2**. FIG. **2** is a perspective view illustrating an end part of the support member **130**.

The extension mast **120** is wound around the support member **130** at a time of storage. At this time, the extension mast **120** is elastically deformed in a way to extend in an axial direction (direction (B)) of the support member **130**.

The extension mast **120** is extended from a wound state at a time of extension. At this time, the extension mast **120** is elastically deformed in a way to extend in an extension direction (direction (A)).

By such elastic deformation, repeatedly performing storing of the extension mast **120** and extending of the extension mast **120** will be possible. Consequently, the extension mast **120** has an area where a transition in shape happens in vicinity of the support member **130**.

There is a case where a local shape change occurs in the support member **130** according to a temperature distribution inside the support member **130**. In such a case, a difference occurs between the extension direction of the extension mast **120** and an extension direction of the solar array bracket **110**. And, there is risk of the difference in the extension directions leading to damage to the solar array bracket **110**.

Consequently, in a winding axial direction (direction (B)), it is necessary to reduce deformation in the support member **130** that is associated with a temperature change. That is, in the direction (direction (B)) that is orthogonal to the extension direction (direction (A)) of the extension mast **120**, closer a coefficient of linear expansion of the material for the support member **130** is to 0, the more preferable.

In space environment, a temperature difference occurs with partial solar radiation and the like as factors.

When having a range of the temperature difference that can occur in the space environment as a condition, it is preferable that the coefficient of linear expansion of the material for the support member **130** is a value within a range that is higher than or equal to -1×10^{-6} [/° C.] and lower than or equal to 1×10^{-6} [/° C.].

The range that is higher than or equal to -1×10^{-6} [/° C.] and lower than or equal to 1×10^{-6} [/° C.] is called "application range".

"° C." means degree Celsius Degree Celsius is also called, simply, "degree".

"/° C." means "per degree", that is, "for each degree Celsius."

In a case where the coefficient of linear expansion of the material for the support member **130** is a value within the application range, damage to the solar array bracket **110** can be prevented.

In a case where the coefficient of linear expansion of the material for the support member **130** is a value outside the application range, a deformation amount of the support member **130** becomes large when the temperature change occurs. For example, when the support member **130** moves from a shade area and begins to receive solar radiation, large deformation occurs in the support member **130** because of a partial rise in a temperature of the support member **130**. And, the large deformation of the support member **130** leads to damage to the solar array bracket **110**.

Therefore, the support member **130** is made of a material that has the coefficient of linear expansion that is higher than or equal to -1×10^{-6}[/° C.] and lower than or equal to 1×10^{-6}[/° C.]. A specific material is a fiber reinforced composite material.

The fiber reinforced composite material is a material made by combining a reinforced fiber and a base material (matrix). By adjusting an orientation of the reinforced fiber, it is possible to make the coefficient of linear expansion a value within the range that is higher than or equal to -1×10^{-6}[/° C.] and lower than or equal to 1×10^{-6}[/° C.].

A method to join the extension mast **120** to the support member **130** will be described based on FIG. **3** and FIG. **4**. FIG. **3** illustrates a cross-section of a joining portion between the support member **130** and the extension mast **120** viewed from the axial direction of the support member **130**. FIG. **4** illustrates, in an enlarged manner, the joining portion viewed from a direction of arrow (a) in FIG. **3**.

The extension mast **120** has a hole processed part **121** near an end. The hole processed part **121** is a portion that is processed to have a hole made.

The support member **130** has a protrusion part **131**. The protrusion part **131** is a portion that is protruded.

The protrusion part **131** is plugged, without a space, into the hole processed part **121**. That is, the protrusion part **131** is filled into the hole processed part **121**. As a result, the extension mast **120** is joined to the support member **130**.

There may be a plurality of sets of the hole processed part **121** and the protrusion part **131**. The number of sets of the hole processed part **121** and the protrusion part **131** can be designed according to a size and the like of the solar array wing **100**.

The protrusion part **131** is shaped such that a cross-section is smaller than the hole processed part **121** to make the protrusion part **131** possible to be inserted into the hole processed part **121**.

The protrusion part **131** is shaped such that a volume is equal to a capacity of the hole processed part **121** to make the protrusion part **131** possible to be plugged, without a space, into the hole processed part **121**. Specifically, the protrusion part **131** is shaped somewhat longer than a depth of the hole processed part **121** (that is, a thickness of the extension mast **120**).

The protrusion part **131** is inserted into the hole processed part **121** and the protrusion part **131** is locally heated to couple the extension mast **120** to the support member **130**.

Then, in the protrusion part **131**, a structure of the matrix in the fiber reinforced composite material changes by heating such that viscosity of the fiber reinforced composite material is lowered. And, the protrusion part **131** is deformed and becomes a same shape as the hole processed part **121**. That is, the protrusion part **131** is filled into the hole processed part **121**.

As a result, the protrusion part **131** is plugged, without a space, into the hole processed part **121**, and the extension mast **120** is coupled to the support member **130**.

Heating the protrusion part **131** locally is enabled by making a high-temperature object come in contact with the protrusion part **131**. The high-temperature object is an object with a temperature that is high. Specifically, the temperature of the high-temperature object is higher than a melting point of the matrix in the fiber reinforced composite material.

A simple and easy method is a method to blow high-temperature gas onto the protrusion part **131** using a hairdryer and the like.

The high-temperature object may be any one of a gas, a liquid, or a solid, regardless of type. A solid that is the high-temperature object, for example, is a tool that is heated to a high-temperature. That is, the tool and the like that are heated to a high-temperature may be made to come in contact with the protrusion part **131**.

The fiber reinforced composite material that is to be the material for the support member **130** will be supplemented.

When a temperature of vicinity of the hole processed part **121** of the extension mast **120** (that is, the hole processed part **121**'s surroundings) at a time of heating the protrusion part **131** becomes higher than or equal to a glass-transition temperature of CFRP, a material for the extension mast **120**, strength of the vicinity of the hole processed part **121** is noticeably lowered.

Therefore, a fiber reinforced composite material such as the following is used for the support member **130**. A temperature at which the structure of the matrix changes such that the viscosity of the fiber reinforced composite material is lowered is below the glass-transition temperature of CFRP, the material for the extension mast **120**.

The temperature at which a structural change of the matrix and lowering of the viscosity of the fiber reinforced composite material happen is called "applicable temperature". The applicable temperature is equivalent to the melting point of the matrix.

For example, in a case where the glass-transition temperature of CFRP is 150° C., the applicable temperature of the fiber reinforced composite material is necessary to be below 150° C.

There is a possibility where the glass-transition temperature of CFRP used for the extension mast **120** becomes lower than a standard temperature (for example, 150° C.) with unevenness in quality and the like of CFRP as causes. Consequently, in a case where a difference between the applicable temperature of the fiber reinforced composite material and the standard temperature of CFRP is small, there is a possibility that the strength of the vicinity of the hole processed part **121** is lowered.

Therefore, it is preferable that a difference between the applicable temperature of the fiber reinforced composite material used for the support member **130** and the standard temperature of CFRP used for the extension mast **120** is higher than or equal to 10° C.

The difference between the applicable temperature of the fiber reinforced composite material used for the support member **130** and the standard temperature of CFRP used for the extension mast **120** is called "temperature difference".

There is no upper limit to the temperature difference. Since the applicable temperature of the fiber reinforced composite material, however, is low, when the temperature difference is too big, the structural change of the matrix in the fiber reinforced composite material and the lowering of the viscosity of the fiber reinforced composite material happen at a time of use in the space environment that there is a possibility of the solar array wing **100** being damaged.

Therefore, it is preferable that the applicable temperature of the fiber reinforced composite material is higher than or equal to 80° C.

In a case where metal is used for the matrix in the fiber reinforced composite material, when a temperature of the matrix exceeds a melting point of the metal, the matrix is liquefied. That is, the structural change of the matrix and the lowering of the viscosity of the fiber reinforced composite material happen.

In a case where resin is used for the matrix in the fiber reinforced composite material, when the temperature of the matrix exceeds a glass-transition temperature of the resin, the matrix is gelled. That is, the structural change of the matrix and the lowering of the viscosity of the fiber reinforced composite material happen.

The glass-transition temperature of CFRP is typically below 300° C. Consequently, the glass-transition temperature of CFRP is below melting points of many metals.

Therefore, using metal for the matrix in the fiber reinforced composite material is preferable. The metal to be used may be a single component metal or may be an alloy. Specific examples of the single component metal are lead (Pb), tin (Sn), bismuth (Bi), cadmium (Cd), copper (Cu), cesium (Cs), gallium (Ga), zinc (Zn), indium (In), and the like.

Generally, metal has higher rigidity than resin. Therefore, using metal for the matrix in the fiber reinforced composite material is preferable to increase rigidity of the support member **130**.

In a case where the support member **130** being lightweight is to be considered important, using resin for the matrix in the fiber reinforced composite material is preferable.

Both metal and resin may be used for the matrix in the fiber reinforced composite material.

Effect of Embodiment 1

According to Embodiment 1, the solar array wing **100** with the solar array bracket **110** that is not prone to damage can be achieved. Specifically, the solar array wing **100** with an extension direction difference between the extension mast **120** and the solar array bracket **110** that is small is achieved. Such solar array wing **100** is achieved by the support member **130**. The support member **130** is possible to reduce the extension direction difference between the extension mast **120** and the solar array bracket **110**. In the support member **130**, there is no clearance between the protrusion part **131** and the hole processed part **121**. A thermal expansion difference between the support member **130** (fiber reinforced composite material) and the extension mast **120** (CFRP) is small.

Embodiment 2

With regard to a form of a support member **130**, differing points from Embodiment 1 will mainly be described based on FIG. **5**.

An example of a structure of the support member **130** will be described based on FIG. **5**. FIG. **5** illustrates a cross-section of a joining portion between the support member **130** and the extension mast **120** viewed from an axial direction of the support member **130**.

The support member **130** includes two columnar shaped parts **132** and a connecting part **133**. The support member **130** is made using a fiber reinforced composite material as described in Embodiment 1.

The two columnar shaped parts **132** are connected by the connecting part **133**.

The columnar shaped part **132** is a member that forms a columnar shape having a plane parallel to the axial direction (length direction). For example, each columnar shaped part **132** forms a semi-cylindrical shape, and is linked, on a plane side, to another columnar shaped part **132** by the connecting part **133**.

The connecting part **133** is a member to connect the two columnar shaped parts **132**. Specifically, the connecting part **133** connects the planes of the two columnar shaped parts **132** to each other. The connecting part **133** is inserted into the hole processed part **121** and utilized as the protrusion part **131**. The connecting part **133** forms a columnar shape.

In a preliminary stage of joining the support member **130** and the extension mast **120**, the connecting part **133** may be joined to one columnar shaped part **132** or may be separated from each columnar shaped part **132**. That is, the connecting part **133** may be integrated with the columnar shaped part **132**, or may be an individual separate from the columnar shaped part **132**. By a protrusion part being provided on each of the two columnar shaped parts **132**, the connecting part **133** may be configured of the two protrusion parts.

Since the connecting part **133** is to be utilized as the protrusion part **131**, a cross-section of the connecting part **133** is smaller than the hole processed part **121**, and a volume of the connecting part **133** is equal to the capacity of the hole processed part **121**.

The connecting part **133** is inserted into the hole processed part **121** provided near the end of the extension mast **120**, and the two columnar shaped parts **132** sandwich a neighborhood of the end of the extension mast **120**. That is, the two columnar shaped parts **132** sandwich the hole processed part **121**'s surroundings.

Then, the connecting part **133** is locally heated, a structural change of a matrix and lowering of viscosity of a fiber reinforced composite material happen in the connecting part **133**, and the connecting part **133** is deformed and plugged, without a space, into the hole processed part **121**. That is, the connecting part **133** is filled into the hole processed part **121**.

As a result, the extension mast **120** is joined to the support member **130**.

Heating the connecting part **133** locally, for example, is performed by conducting electricity to the extension mast **120**.

By conducting electricity to the extension mast **120**, heat is generated in CFRP, the material for the extension mast **120**, and the heat that is generated is conducted to the connecting part **133**. As a result, the connecting part **133** is heated.

In a case where the fiber reinforced composite material, the material for the support member **130**, is a conductor, heating the connecting part **133** locally can be performed by conducting electricity to the columnar shaped part **132**.

By conducting electricity to the columnar shaped part **132**, heat is generated in the columnar shaped part **132**, and the generated heat is conducted to the connecting part **133**. As a result, the connecting part **133** is heated.

In a case where the fiber reinforced composite material, the material for the support member **130**, does not conduct enough electricity, the connecting part **133** can be heated by adding a metal wire to the support member **130** and conducting electricity through the metal wire. The metal wire may be buried in the support member **130**, or may be wired on a surface of the support member **130**.

Effect of Embodiment 2

According to Embodiment 2, since the hole processed part **121**'s surroundings are sandwiched by the two columnar shaped parts **132**, strength in joining of the support member **130** and the extension mast **120** can be increased.

Supplement to Embodiments

Each embodiment is exemplification of a preferred mode, and is not intended to limit the technical scope of the present disclosure.

REFERENCE SIGNS LIST

100: solar array wing; **110**: solar array bracket; **120**: extension mast; **121**: hole processed part; **130**: support member; **131**: protrusion part; **132**: columnar shaped part; **133**: connecting part; **140**: beam.

The invention claimed is:

1. A solar array wing comprising:

an extension mast to be extended from a wound state; and

a support member, around which the extension mast is wound, to support the extension mast after the extension mast is extended, wherein

the support member is made of a fiber reinforced composite material,

a coefficient of linear expansion of the fiber reinforced composite material, a unit of which is for each degree Celsius, in a direction that is orthogonal to an extension direction of the extension mast, is higher than or equal to -1×10^{-6} and lower than or equal to 1×10^{-6},

the extension mast is made of carbon fiber reinforced plastic, and

in the fiber reinforced composite material of the support member, a matrix having a melting point below a glass-transition temperature of the carbon fiber reinforced plastic of the extension mast is used.

2. The solar array wing according to claim **1**, wherein
the support member has a protrusion part, and
the extension mast has a hole processed part in which a hole is made and into where the protrusion part is inserted and is joined to the support member by the protrusion part being plugged, without a space, into the hole processed part.

3. The solar array wing according to claim **1**, wherein the support member includes;
two columnar shaped parts that form columnar shapes having planes parallel to an axial direction of the support member, and
a connecting part that connects the planes of the two columnar shaped parts to each other.

4. The solar array wing according to claim **3**, wherein
the extension mast has a hole processed part in which a hole is made and into where the connecting part is inserted, and
the extension mast is joined to the support member by the connecting part being plugged, without a space, into the hole processed part.

5. The solar array wing according to claim **3**, wherein the extension mast is disposed between the two columnar shaped parts.

6. The solar array wing according to claim **3**, wherein the extension mast is disposed between the planes of the two columnar shaped parts.

7. The solar array wing according to claim **2**, wherein the protrusion part of the support member is formed of the fiber reinforced composite material of the support member.

8. The solar array wing according to claim **3**, wherein the connecting part is disposed between the two columnar shaped parts.

9. The solar array wing according to claim **3**, wherein the connecting part is disposed between the planes of the two columnar shaped parts.

10. The solar array wing according to claim **3**, wherein the connecting part of the support member is formed of the fiber reinforced composite material of the support member.

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